Assessment of Roadway Surface Conditions Using On-Board Vehicle Sensors

Project Overview

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Discussion Outline

- Research objective and scope
- Tire/Road Friction background
- Proposed assessment concept
- Vehicle instrumentation installation
- Experimental data collection
- Data analysis
- Conclusions

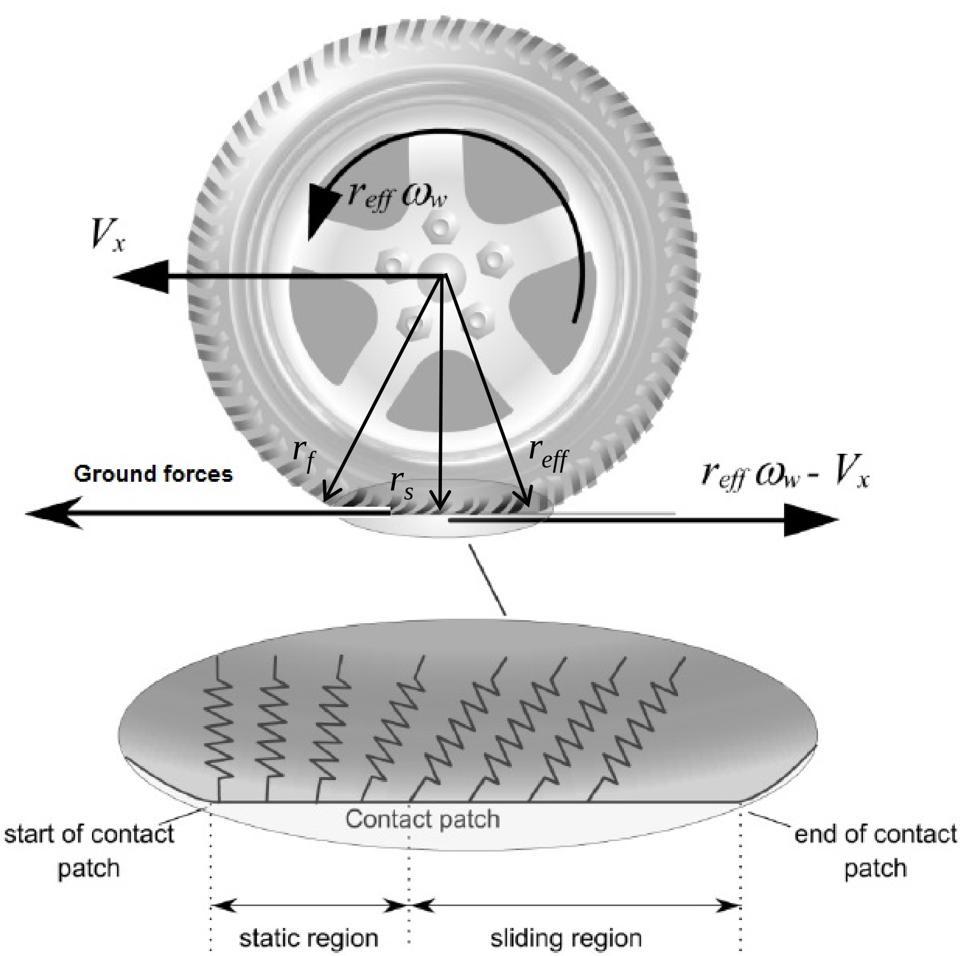
Research Objective and Scope

- Assess in real-time road surface friction using the relative rotational displacement rates of vehicle wheels in controlled driving conditions

- Use the Smart Road facility to collect relevant data from test vehicle(s) under specific target weather conditions

Friction Background (at driving wheel)

- Friction forces = forces applied to tires at contact patch
- Effective rolling radius
- Longitudinal slip ($r_{eff}\omega_w$ -V_x) (net velocity)
- Micro-slip (detects road condition)
- Macro-slip (activates control sensors)
- Rolling resistance = Loss of energy (opposed to V_x)
- Tire/Road parameters effects



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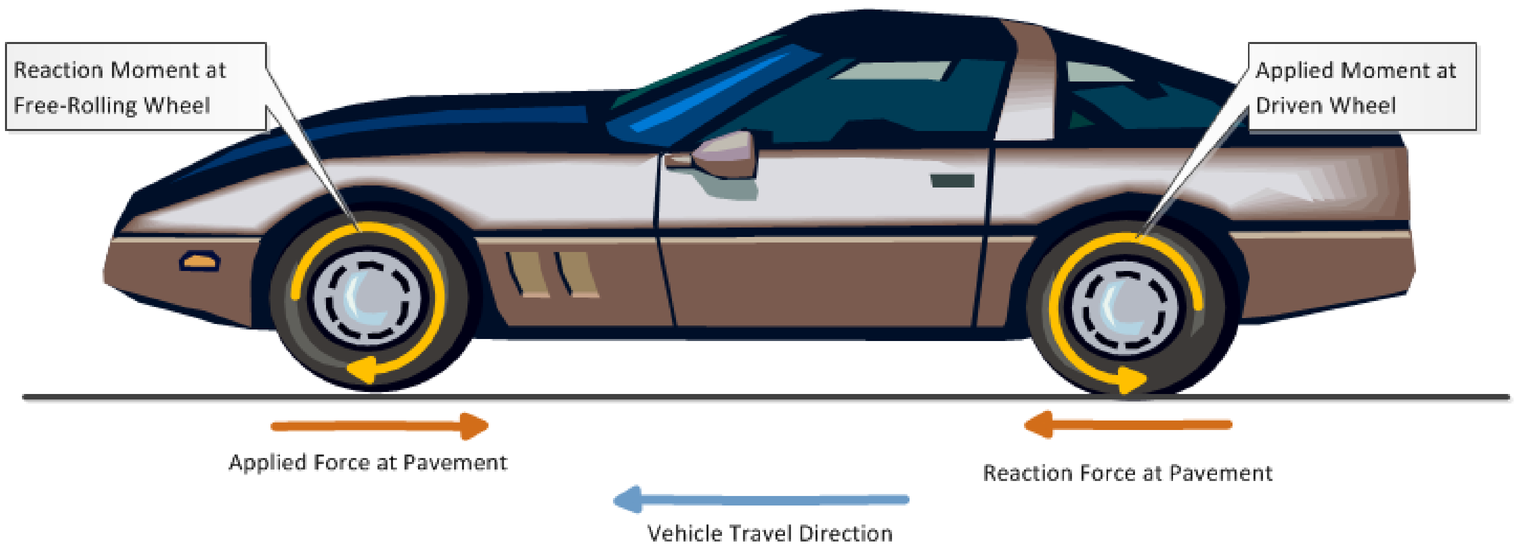
Proposed Concept



- Slip results in under- or over-rotation of wheels with respect to vehicle distance traveled
- Opposing slip effects at the wheels (V = constant)
- Traction loss (slip) leads to driving wheels rotate more than free-rolling wheels

Proposed Concept (cont'd)

Slip is the under- or over-rotation of wheel with respect to vehicle distance traveled

$$\uparrow \; slip\ at\ drive\ wheel \;\rightarrow \uparrow pulses$$

$$\uparrow \; slip\ at\ freerolling\ wheel \rightarrow \downarrow ?\, pulses$$

Where: $\mathrm{P_D} = \text{pulses at driving wheel}$

$\mathrm{P_F}$ = pulses at free-rolling wheel

As traction $\downarrow$ $(slip \;\uparrow)$ $\quad \boldsymbol{P_D/PF} \uparrow$

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Methodology - Vehicle and Instrumentation

- RWD (Tahoe) and FWD (Impala)
- NextGen data acquisition system (DAS)
- Controller area network (CAN) bus interface module (for communication inside the vehicle)
- Head unit incorporating an inertial measurement unit (IMU)
- Differential GPS (DGPS)
- Network box (interfaces with the vehicle on-board computer)

Data Analysis - Calculation Formulas

- Spherical Law of Cosines to calculate traveled distance from DGPS data (latitude, longitude, altitude)

- Relative Driven Displacement (RDD) ratio

  RDD = DGPS CalcDist/DistCalcPulsDriven

- Relative Undriven Displacement (RUD) ratio

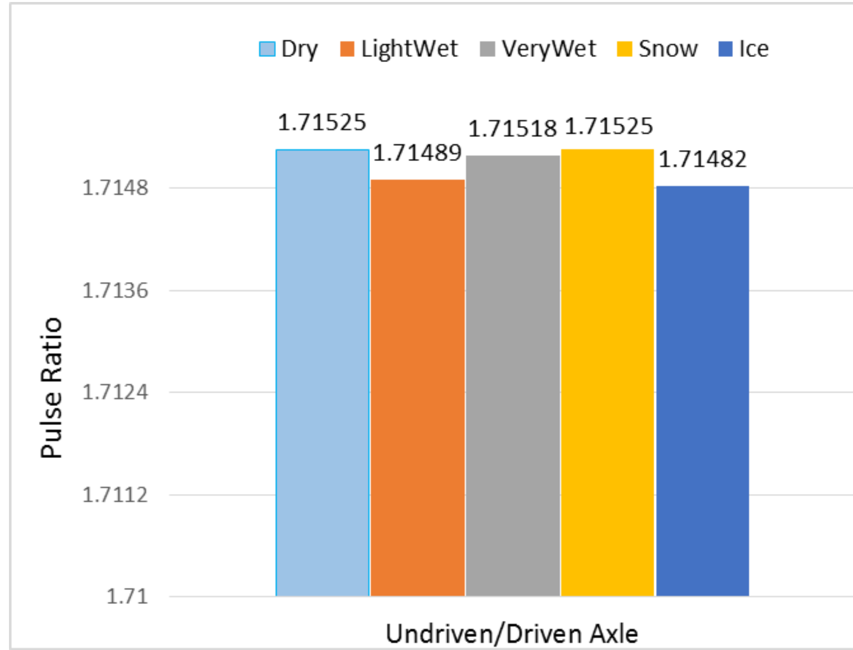
  RUD = DGPS CalcDist/DistCalcPulsUndriven

- Relative Rotational Displacement (RRD) ratio
  - RRD = RUD/RDD = Total No. of Pulses (N) x Wheel Circumference (C)

- Compute ratios for undriven/driven wheel pulses

- Compare RRD and pulse ratios across number of trips and roadway conditions (dry, wet, etc.)

Statistical Results Summary – T-test and ANOVA (RWD)



Statistical analyses showing differences between groups of data for various road surface conditions

	T-test (α = 0.05)				
	Dry	LightWet	VeryWet	Snow	Ice
Dry					
LightWet					
VeryWet					
Snow					
Ice					
	ANOVA (α = 0.05)				
Legend	P < α => Stat Diff		P > α => No Stat Diff		

Lessons Learned

- Wheel sensor pulse counts are repeatable over multiple passes over the same distance at very low speeds (5 MPH)
- Speed variations do not result in different pulse counts over the same vehicle travel distance (35 - 50 MPH)
- Influence of tire pressure (15 - 40 PSI) on pulse count over the same distance is minimal at very low speeds (5 MPH)
- Inertial measurement system based on differential GPS at 20 Hz results in distance measurement variability (vehicle travels 1.4 ft. in 1/20 sec.)
- Side-to-side tire swap has minimal effect on wheel pulse count when vehicle travels the same distance
- Running each test condition 30 times does not increase statistical power over 10 times

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Conclusions

- Assessment of traction using OEM on-board sensors for both RWD and FWD vehicles is possible.
- Traction on frozen precipitation (dry snow, wet snow, slush) is complex and varies widely depending upon layering, air temperatures, traffic, etc.
- Very wet pavement may provide very good traction as long as hydroplaning does not occur. Lightly wet roads may provide very poor traction due to contaminants on the pavement.
- More slippage occurred at both front and rear axles on lightly wet and icy surfaces for both FWD and RWD vehicles.
- Analyses of the test results showed statistically significant differences across all road surface conditions (dry, wet, etc.)